



CLASSIFICATION AND EVALUATION OF CHARACTERISTIC SHAPES OF MATERNITY PONCHOS USING A MACHINE LEARNING ALGORITHM

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ABSTRACT: The present study presents results of classification and evaluation of poncho shapes for pregnant women using radius-vector functions and machine learning algorithms. 30 digital images were analyzed, based on which six main shapes were identified: rectangular, oval, round, asymmetric, hooded, and V-shaped. Using feature selection methods, the most informative features were determined, and the models were grouped using Euclidean metrics and compared with expert assessment. The results show that the most common are V-shaped, oval, and hooded models, which form about 80% of the examples and are distinguished by comfort, functionality, and aesthetics. Based on the analysis, a universal adaptive poncho model was developed, combining the preferred shapes and structural elements, providing comfort and freedom of movement for different stages of pregnancy and the postpartum period. The study offers guidelines for the modern design of maternity clothing.

Keywords: Maternity Poncho, Shape Classification, Machine Learning, Image Analysis, Adaptive Clothing.

KLASIFIKACIJA I PROCENA KARAKTERISTIČNIH OBLIKA PONČA ZA TRUDNICE KORIŠĆENJEM ALGORITMA MAŠINSKOG UČENJA

APSTRAKT: U ovoj studiji su predstavljeni rezultati klasifikacije i evaluacije oblika ponča za trudnice korišćenjem funkcija radijus-vektor i algoritama mašinskog učenja. Analizirano je 30 digitalnih slika, na osnovu kojih je identifikovano šest glavnih oblika: pravougaoni, ovalni, okrugli, asimetrični, sa kapuljačom i u obliku slova V. Koristeći metode selekcije karakteristika, određene su najinformativnije karakteristike, a modeli su grupisani korišćenjem euklidskih metrika i upoređeni sa procenom stručnjaka. Rezultati pokazuju da su najčešći modeli u obliku slova V, ovalni i sa kapuljačom, koji čine oko 80% primera i odlikuju se udobnošću, funkcionalnošću i estetikom. Na osnovu analize, razvijen je univerzalni adaptivni model ponča, koji kombinuje preferirane oblike i strukturne



elemente, pružajući udobnost i slobodu kretanja za različite faze trudnoće i postporođajni period. Studija nudi smernice za savremeni dizajn odeće za trudnice.

Ključne reči: Pončo za trudnice, Klasifikacija oblika, Mašinsko učenje, Analiza slike, Adaptivna odeća.

1. INTRODUCTION

Adaptive and versatile maternity clothing is an important segment in the modern fashion industry, where comfort, functionality, and aesthetics are important [1, 2]. The poncho has emerged as a preferred model due to its loose fit and ability to provide space and comfort for different body types, including expectant mothers [3].

The influence of traditional forms and motifs characteristic of the poncho is traced in a number of ethnic and cultural contexts, such as the Mexican and Navajo styles, which contribute to the development of modern design solutions [4].

There is no systematic classification of poncho forms that simultaneously takes into account comfort, space, and aesthetics.

Most of the existing research focuses on the traditional and cultural aspects of the poncho, but not on its applicability for pregnant women in modern design. This makes it difficult to select optimal models that meet the specific needs and preferences of this consumer segment.

The development of clothing classification and evaluation technologies based on machine learning and digital images provides new perspectives for analyzing characteristic shapes and selecting optimal clothing models [5]. Radius-vector functions are used as a tool for extracting geometric features, and the selection of shape coefficients allows for precise classification and objective assessment of silhouettes [6].

The aim of the study is to classify and evaluate shapes of maternity ponchos based on radius-vector functions and machine learning. By integrating expert assessment, a universal and adaptive model for clothing suitable both during pregnancy and in the postpartum period is sought.

2. MATERIAL AND METHODS

Digital images of garments from accessible Internet sites were used. After downloading, the files were processed with an online artificial intelligence tool, Copilot (Microsoft Corp., Redmond, WA, USA). This tool extracted only the garments from the photos and gave them a new look, different from the original. The background of the image was removed. The final files were saved in *.PNG format.

Radius-vector functions were used to analyze the characteristic shapes of maternity clothes and their images. From each image, 5 form coefficients, FI1, FI2, FI3, FI4, and FI5, were calculated.

The form indices have the following form [7]:

$$FI1 = \frac{1}{\pi} \int_0^{\pi} \frac{|R(\theta) - R(\pi - \theta)|}{\bar{R}} d\theta \quad (1)$$

$$FI2 = \frac{R(\theta_{max})}{\bar{R}} \quad (2)$$

$$FI3 = \frac{R_{max}}{\bar{R}} \quad (3)$$

$$FI4 = \frac{1}{2\pi} \int_0^{2\pi} \frac{|R_t(\theta) - R_0(\theta)|}{\bar{R}_0} d\theta \quad (4)$$

$$FI5 = \sqrt{\frac{1}{2\pi} \int_0^{2\pi} (R'(\theta) - \bar{R}')^2 d\theta} \quad (5)$$

where $R(\theta)$ is a radius-vector function; $\bar{R}$ is the average value of $R(\theta)$; R_{max} is the largest radius, relative to the center of gravity of the object; the angle θ changes in the interval $\theta \in [0, 2\pi]$; $R_t(\theta)$ is the current value of the radius; $R_0(\theta)$ is the initial radius; $R'(\theta)$ is the first derivative of the radius-vector function $R(\theta)$ with respect to the angle θ .

Using the methods RReliefF, FSRNCA and SFCPP [8], the three most informative coefficients were selected. These three shape coefficients were used to represent the clothing models in three-dimensional space.

An algorithm with a Euclidean distance function was used to compare the real images with the characteristic shapes of clothing for pregnant women. This distance (d) was calculated using the following formula:

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2} \quad (6)$$

where x_1 , y_1 and z_1 are coordinates in the three-dimensional space of the characteristic shape of the clothing for pregnant women; x_2 , y_2 and z_2 are coordinates of the shape indices of the real image of the clothing. The characteristic shapes of ponchos are shown in Figure 1. The images were downloaded from accessible literature sources [2, 3, 4], then redrawn and stylized. Six basic shapes of ponchos are presented, indicated by a code. These include rectangular (SP1), oval (SP2), round (SP3), asymmetrical (SP4), hooded (SP5) and V-shaped (SP6). The indicated ponchos have their own shape and method of manufacture, which allows them to look different and be worn in different ways.

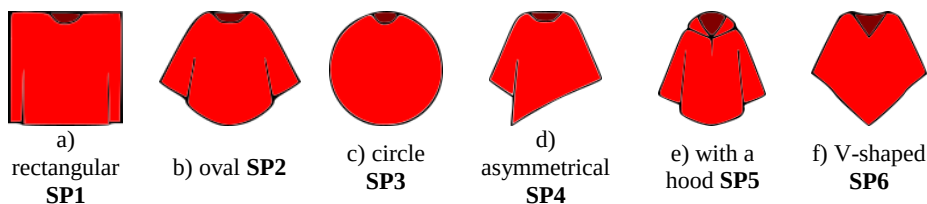


Figure 1: Characteristic shapes of ponchos

Table 1 lists the websites from which the poncho images were downloaded. For each model, the specific website from which the image was downloaded, the date the site was accessed, and the number of photos taken from it are listed. The analysis covers a total of 30 images collected from various online fashion, retail, and vintage clothing platforms, such as HSN, Farfetch, Vestiaire Collective, eBay, and others.

Table 1: Description of the clothing photos used

Model number	Internet source	Accessed on	Number of images
P1,P2	https://www.hsn.com/	05.08.2025	2
P3,P4,P5	https://mania.bg	12.01.2026	3
P6,P7,P8,P9	https://www.farfetch.com/	12.01.2026	3
P10,P11	https://us.vestiairecollective.com/	12.01.2026	3
P12,P13, P14	https://www.aboutyou.bg/	11.08.2025	3
P15	https://www.ebay.com/	21.07.2025	1
P16	https://www.baltini.com/	21.07.2025	1
P17	https://www.johnlewis.com/	18.07.2025	1
P18	https://thefoldline.com/	15.08.2025	1
P19,P20	https://vintagebymisty.com/	15.08.2025	2
P21	https://www.lyst.com/	18.08.2025	1
P22	https://echonewyork.com/	18.08.2025	1
P23, P24,P25	https://answear.bg/	18.08.2025	3
P26	https://www.theredclosetdiary.com/	16.08.2025	1
P27	https://newlife-baby.com/	16.08.2025	1
P28,P29	https://www.faire.com/	22.07.2025	2
P30	https://shopstyle.bg/	16.08.2025	1
-	-	Total	30

Figure 2 presents the poncho models used in the study, each with an identifier from P1 to P30. The images have a variety of shapes, colors and cuts. Among them, ponchos with fringes, hoods, asymmetrical silhouettes and various decorative elements stand out, as well as combinations of different shapes. Poncho models can be grouped by shape. V-shaped (P1, P2, P13, P14, P18, P19, P22, P28) with classic or softened silhouettes. Rectangular and straight (P6, P7, P8, P16, P21, P25, P27, P30) with varying degrees of structure. Oval and round (P3, P5, P9, P10, P11, P15) with smooth lines and decorative accents. Asymmetrical/combined (P4, P12, P17, P20, P23, P26, P29) with slanted, elongated or mixed shapes and additional details.

The study involved three subject matter experts (S1, S2, and S3). They were individually surveyed using a structured form containing the images of the analyzed models (P1–P30). For each image, they indicated belonging to one of the six predefined forms (SP1–SP6), without prior information about the results of the algorithmic classification. The obtained scores were used for comparative analysis with the automatic results and to assess the accuracy and limitations of the applied methodology.



Figure 2: Poncho clothing models

3. RESULTS

Using the selection methods RReliefF, FSRNCA, and SFCPP, it was found that in all three choices, the most informative compared to the other shape indices are FI2, FI4, and FI5. Figure 3 shows the grouping of poncho models according to characteristic shapes, determined by distance functions. The results of the distance functions show a strongly unbalanced distribution between the shapes. The most common is SP5 (with a hood) – 13 models (over 40%), followed by SP2 (oval) with 7 models and SP4 (asymmetrical) with 5 models, while SP6 (V-shaped) is represented by only 3 models, SP3 (round) with 1, and SP1 (rectangular) also with 1 model. The equating of most shapes to SP5 is due to the fact that the shape indices more easily capture the general volumetric shape and roundness

characteristic of a hooded poncho. They do not distinguish well enough specific features of shapes such as the V-shaped line (SP6), rectangular geometry (SP1), or circular shape (SP3).

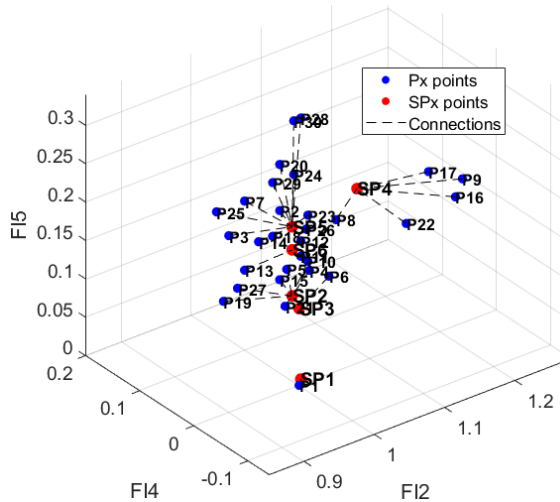


Figure 3: Correspondence to an image of a poncho with a characteristic shape

Table 2 shows the grouping of the characteristic shapes according to the results of the distance function and the classification of three experts in the subject area.

Table 2: Correspondence of an image of a poncho with a characteristic shape

P	D	S1	S2	S3	P	D	S1	S2	S3
P1	SP1	SP6	SP1	SP6	P17	SP4	SP4	SP5	SP4
P2	SP5	SP6	SP2	SP6	P18	SP5	SP6	SP6	SP6
P3	SP5	SP2	SP3	SP2	P19	SP2	SP6	SP1	SP6
P4	SP2	SP4	SP4	SP4	P20	SP5	SP4	SP2	SP2
P5	SP2	SP3	SP5	SP2	P21	SP2	SP1	SP3	SP6
P6	SP3	SP5	SP6	SP1	P22	SP4	SP2	SP4	SP2
P7	SP5	SP1	SP2	SP1	P23	SP5	SP4	SP5	SP4
P8	SP4	SP1	SP1	SP1	P24	SP5	SP5	SP6	SP5
P9	SP4	SP1	SP3	SP6	P25	SP5	SP1	SP1	SP6
P10	SP2	SP2	SP4	SP2	P26	SP5	SP6	SP2	SP6
P11	SP6	SP3	SP5	SP4	P27	SP2	SP1	SP3	SP1
P12	SP6	SP5	SP6	SP4	P28	SP5	SP2	SP4	SP4
P13	SP6	SP6	SP1	SP4	P29	SP5	SP6	SP5	SP5
P14	SP5	SP2	SP2	SP4	P30	SP5	SP1	SP6	SP1
P15	SP2	SP2	SP3	SP6	-	-	-	-	-
P16	SP4	SP1	SP4	SP6	-	-	-	-	-

P-poncho; D-distance; Sx-specialist; Px-poncho number; SPx-basic poncho shape

Compared to the manual classification, where SP1 and SP6 are much more strongly represented, an underestimation of these groups is seen here, which is an indication that the distance function used has limited sensitivity and leads to incorrect classifications. The material from which the poncho is made also affects the perception and classification of the shape. This explains the differences in the opinions of the experts or incorrect recognitions by the algorithm.

Figure 4 shows a graph of the percentage of correspondence between poncho images and characteristic shapes. The most common shapes are the V-shaped, oval, and hooded, forming a total of almost 80% of all observed models, which clearly shows market preferences and contemporary design trends. These shapes are particularly suitable for pregnant women, as they provide sufficient space and comfort while maintaining the elegant shape of the garment. The asymmetrical shape is also found and has the potential to create modern design solutions suitable for pregnant women. The rectangular and round shapes are less common, with the round one being defined as a niche segment. The presence of combined shapes and models with additional details indicates an interest in innovation and variations on the basic shapes, which can also be adapted for maternity clothing.

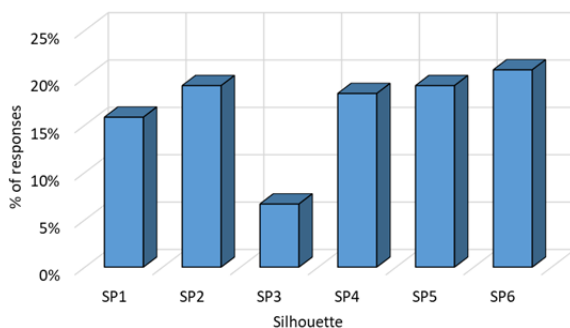


Figure 4: Percentage of responses matching poncho images with characteristic shapes

From the analyses made, it can be summarized that when developing a real poncho model, the priority should be on the most popular shapes and combinations between them, while less common ones, such as the round one, can be used for niche or limited products, especially if combined with additional details or specific materials.

The proposed poncho model combines an oval shape, a V-neck, and a hood for maximum comfort and style. It is made of soft wool, cashmere, or jersey with ethnic motifs and short fringes; it offers a loose cut, suitable for different body types, including pregnant women. Universal and adaptable, the model is complemented by asymmetrical and decorative elements for a contemporary look and meets current trends in clothing design for expectant mothers.

The poncho construction (figure 5) includes a rectangular or oval-shaped base fabric and universal dimensions (width 120–140 cm, length 80–100 cm), providing a loose and comfortable fit. A V-neck is formed in the front (20–30 cm wide, 25–35 cm deep), and a separately constructed hood of two symmetrical parts (25–30 × 35–40 cm) adds

functionality. Asymmetric or decorative panels ($10-15 \times 60-80$ cm) located in the shoulder area are also included for a modern look. For adaptability, the model is complemented by a belt (length 120–180 cm, width 3–6 cm), which passes through hidden nuts located on the side and/or on the back, providing stability and the ability to adjust according to the physique.

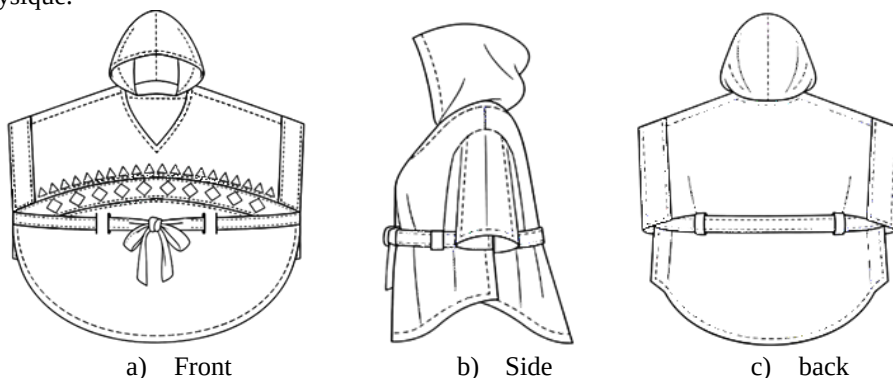


Figure 5. Textile patterns of developed poncho model

The AI generative model Copilot was used to visualize the proposed poncho model. This visualization is presented in Figure 6. The images demonstrate options for how the garment is worn. The three options are with a hood and belt, a frontal view with emphasized drapery, and a silhouette on a figure in a natural stance. The visualization emphasizes the loose cut, decorative edges, and adaptability of the model.



Figure 6. AI visualization of a poncho model

Technological operations for making a poncho with a removable belt are proposed, systematized in table 3.

The main fabric is cut according to the pattern (oval or rectangular), marking all the structural elements – neckline, hood, decorative panels, and places for attaching the belt.

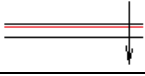
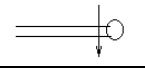
The hood is made of two symmetrical details (25–30 × 35–40 cm), joined along the upper edge, processed with an overlock, and sewn to the neckline.

The V-shaped neckline is edged with a strip of the main fabric, reinforced with a connecting and decorative seam. The side edges are finished with an overlock, and fringes (5–8 cm) can be added for decoration if needed, along with ethnic designs and extra details on the edges.

The belt is made to individual sizes, hemmed and reinforced if necessary, and the edges can be decorated. For fixing, eyelets/nuts from the main fabric are provided, located laterally and/or on the back, ensuring silhouette adjustment. Depending on the design solution, either vertical eyelets or nuts are used, with one option excluding the other.

In the final stage, the poncho is ironed, the symmetry and quality of the seams are checked, and the belt is adjusted to the product with adjustments if necessary for optimal comfort and a finished look.

Table 3: Technological sequence for making a poncho for pregnant women

№	Operation name	Stitch symbol	Stitch type	Note
00.00	Cutting and release	-	-	-
00.01	Rolling, cutting, assembling and numbering	-	-	-
00.01	Gluing of cut necks and cut neckline with knitted backing, nuts and belt (if necessary)	-	-	Iron
00.03	Preparation for work and release of the tufts	-	-	-
01.00	Front parts - main fabric	-	-	-
01.01	Passing a connecting stitch row on the strip of main fabric with the neckline cut		301	At the beginning and at the end of the tightening
01.02	Ironing to the length of the product		-	Iron
01.03	Passing a decorative stitch row		301	-
01.04	Ironing the front part	-	-	Iron
01.05	Marking the location of the buttonholes (for the belt)	-	-	Handmade
02.00	Back parts - main fabric	-	-	-
02.01	Marking the location of the buttonholes (for the belt)	-	-	Handmade
03.00	Hood	-	-	-
03.01	Passing a connecting stitch row on the inner seams of the hood		301	At the beginning and at the end of the tightening
03.02	Passing a 3-end overlock on the inner seams of the hood		504	-



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№	Operation name	Stitch symbol	Stitch type	Note
03.03	Bending the outer edge of the hood		-	Iron
03.04	Passing by folding the hem of the hood		301	-
03.00	Nuts/buttonholes for the belt	-	-	-
03.01	Making and cutting belt nuts		301	-
03.02	Smoothing	-	-	-
03.03	Making buttonholes on the front and back of the poncho (according to the width of the belt)	-	-	-
03.00	Belt	-	-	At the beginning and at the end of the tightening
03.01	Passing connecting inner seams of the belt		301	Handmade
03.02	Turning	-	-	At the beginning and at the end of the tightening
03.03	Passing front seams of the belt		301	Iron
03.04	Smoothing the belt	-	-	-
04.00	Assembly	-	-	At the beginning and at the end of the tightening
04.01	Attachment of the hood to the neckline		301	-
04.02	Passing 3 final overlocks on inner seams of the hood and neckline		504	-
04.03	Sewing ethnic motifs and asymmetrical panels to the main fabric		301	-
04.04	Passing the hem		301	-
05.00	Finishing operations	-	-	-
05.01	Thread cleaning		P	-
05.02	OTK	-	P	-
05.03	Final T&C	-	Ю, II	-
05.04	Dimension control of the finished product	-	P	Iron
05.05	Labeling	-	P	-



4. DISCUSSION

Designing maternity clothing requires a combination of ergonomic comfort, anthropometric adaptability, and aesthetics. The analysis of the developed poncho model against the literature confirms its functional validity and innovative nature.

The main constructive volume (width 120-140 cm, oval silhouette) corresponds to the requirements of Das [9] for freedom of movement and absence of pressure in the abdominal area. The technological allowance allows adaptation to changes in body dimensions without limiting comfort.

Functional adaptability is realized through an adjustable belt (up to 180 cm) and positioned nuts in the waist and back area, which complements the observations of Quintero Rodriguez, C., & Troynikov [10] on transforming clothing. This solution provides control over the silhouette during the different stages of pregnancy and the postpartum period.

The aesthetic characteristics of the model complement the results of Parras-Burgos et al. [11], as the V-neck and the asymmetrical decorative panels (60–80 cm) visually balance the silhouette and contribute to a modern look. Additional decorative elements enhance the individual character of the product without compromising functionality.

The proposed poncho model integrates ergonomic and aesthetic principles, confirming that through adjustable structural elements and appropriate geometry, clothing with sufficiently high functionality and visual value for the modern pregnant woman can be achieved.

5. CONCLUSION

This paper proposes a classification and evaluation of poncho shapes for pregnant women by integrating radius-vector functions, feature selection, and machine learning algorithms. The analysis of 30 images showed trends in contemporary adaptive clothing design, with the most preferred models being hooded, oval, and V-shaped silhouettes.

Based on the results obtained, a universal adaptive poncho model was developed, presented through its construction and manufacturing technology. The poncho model combines the most preferred shapes and structural elements – oval base, V-shaped neckline, hood, decorative panels, and adjustable belt. The model provides comfort, functionality, and aesthetics for the different stages of pregnancy and the postpartum period.

Visualization using an AI model confirms the applicability of the structural solutions and demonstrates various wearing options.

The comparison between automatic classification and expert assessment shows limitations of the distance function used, especially in distinguishing specific shapes such as rectangular, circular, and V-shaped. This highlights the need to expand the set of geometric and visual features for more precise classification of clothing shapes.



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